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Upper body skin-fold thickness is related to race performance in male Ironman triathletes

Short title: Skin-fold thickness and Ironman triathlon performance

Abstract

We investigated the association between skin-fold thickness and race performance in male and female Ironman triathletes. Skin-fold thicknesses at 8 sites and percent body fat were correlated to total race time including the split times for the 3 sub disciplines, for 27 male and 16 female Ironman athletes. In the males, percent body fat ($r = 0.76$; $p < 0.0001$), the sum of upper body skin-folds ($r = 0.75$; $p < 0.0001$) and the sum of all 8 skin-folds ($r = 0.71$; $p < 0.0001$) were related to total race time. Percent body fat ($r = – 0.67$; $p < 0.001$), the sum of upper body skin-folds ($r = – 0.63$, $p = 0.0004$) and the sum of all 8 skin-folds ($r = – 0.59$; $p < 0.001$) were also associated with speed in cycling during the race. In the females, none of the skin-fold thicknesses showed an association with total race time, average weekly training volume or speed in the sub disciplines in the race. The results of this study indicate that low skin-fold thicknesses of the upper body are related to race performance in male Ironman triathletes, but not in females.

Key words: long-distance triathlon – body fat – anthropometry – gender – body composition

Introduction

Ironman Triathlons over 3.8 km swimming, 180 km cycling and 42.2 km running are increasing in popularity. Every year, more and more athletes participate in these races to qualify for the Ironman World Championship in Hawaii [15].

Finishing such an ultra-endurance race needs an enormous physical effort. A special kind of body anthropometry may sustain this type of performance in the fastest possible time. For short-distance triathletes, Landers et al. [10] found that low levels of body fat were important for total race time and most of the sub-disciplines, and longer segmental lengths were important for a successful swimming outcome. According to Sleivert & Rowlands [18], male elite triathletes were of average to light weight and had low levels of body fat.

In contrast to these anthropometric findings, Leake & Carter [11] concluded that training parameters such as training distance, training time and training experience in years were more important than anthropometric measurements in the prediction of performance in short-distance triathletes. According to O'Toole [17], training distances appear to be more important than training paces in preparation for an ultra-endurance triathlon.

Regarding body fat, the relationship between skin-fold thicknesses and running performance has been intensely investigated in runners. Hagan et al. [6] demonstrated that apart from other variables, the sum of 7 skin-fold thicknesses is correlated to marathon performance time. Total skin-fold thickness, the type and frequency of training and the number of years running were the best predictors of running performance and success at the 10 km distance according to Bale et al. [4]. In recent studies, a relationship between the thicknesses of selected skin-folds and running performance has been demonstrated in top class runners [1, 13]. In these studies, elite runners of distances from 100 m to 10,000 m and the marathon had been investigated [1, 13]. High correlations were found for both the front thigh and medial calf skin-fold thickness with 10,000 m race times in male runners. Marathon race time and both the iliac crest and abdominal skin-fold thicknesses were associated in female runners [1]. It is supposed that the skin-fold thicknesses of the lower limb are a result of intense training in running [13]. Evidence suggests gender specific differences of skin-folds in the marathon performance prediction [14] and that physical training affects skin-folds in men and women differently [9].

The relationship between skin-fold thicknesses and race performance was investigated in all running distances from 100 m to 10,000 m and the marathon distance in both male and female top level long-distance runners, but not in recreational long-distance triathletes such as Ironman triathletes. We therefore intended to investigate whether correlations between skin-fold thicknesses and race performance in recreational male and female Ironman triathletes exist. In an Ironman triathlon, athletes have to run the marathon after the swim and bike split, when they are tired. Performance in the run will be affected by exhaustion after swimming and cycling. However, skin-fold thicknesses and body fat should not be affected by exhaustion and tiredness.

Methods

Race and athletes

The organiser of the IRONMAN SWITZERLAND in 2007 contacted all participants via a separate newsletter 3 months before the race and asked them to participate in our investigation. Forty male and 20 female Caucasian non-professional Ironman triathletes were interested in our study; 30 male and 18 female athletes entered the investigation. The subjects were informed of the experimental risks and gave their informed written consent prior to the investigation. The investigation was approved by the Institutional Review Board for use of Human subjects. Twenty-seven male Ironman triathletes with (mean and SD) 39.3 (9.2) years, 1.78 (0.06) m body height, 79.6 (10.3) kg body mass and a BMI of 24.8 (2.4) kg/m^2 and 16 female athletes with 36.6 (7.0) years, 1.66 (0.06) m body height, 59.8 (6.2) kg body mass and a BMI of 21.5 (1.0) kg/m^2 out of our study group finished the race successfully within the time limit. Three male and 2 female triathletes had to give up due to medical complications. On 24th June 2007, IRONMAN SWITZERLAND took place in the heart of the city of Zurich, Switzerland. A total of 1,950 male and female Ironman triathletes from 49 countries started in the morning at 07:00 a.m. The air temperature was 17 °Celsius and the water in Lake Zurich was 20 °Celsius. Due to the low water temperature, wet suits were allowed. Relative humidity was 88 % at the start of the race, 43 % at noon and 41 % in the evening. At the start, the sky was blue and became cloudy slowly during the afternoon and evening. The highest temperature, 25 °Celsius, was reached in the afternoon. The athletes had to swim 2 laps in the lake to cover the 3.8 km distance, and then had to cycle 3 laps of 60 km each which was followed by running 4 laps of 10.5 km each. In the cycling part, the highest point to climb from Zurich (400 metres above sea level) was the ‘Forch’ (700 metres above sea level) while the running course was completely flat in the city of Zurich. Nutrition was provided during the cycling and running courses by the organisers. They offered bananas, energy bars, energy gels and carbohydrate drinks as well as caffeinated drinks and water on the cycling course. On the running course, in addition to the aforementioned nutrition, different fresh fruits, dried fruits, nuts, chips, salt bars and soup were provided.

Measurements and calculations

Before the start of the race, every participant underwent anthropometric measurements in order to determine body mass, body height, limb circumferences and skin-fold thicknesses to calculate BMI, sum of upper body skin-fold thicknesses, sum of lower body skin-fold thicknesses, the total sum of 8 skin-fold thicknesses and percent body fat. Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm Germany) to the nearest 0.1 kg. Circumferences of the upper arm and calf were measured at the right side and at the widest circumference of the limb to the nearest 0.1 cm. At the thigh, circumference was determined 20 cm above the upper pole of the patella. Circumference of the hip for females was measured at the level of the *trochanter major* to the nearest 0.1 cm. Skin-fold thicknesses of pectoralis, axillar (vertical), triceps, subscapular, abdominal (vertical), suprailiacal (at anterior axillary), front thigh and medial calf were measured using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm at the right side of the body. One trained investigator took all skin-fold measurements as inter-tester variability is a major source of error in skin-fold measurements. An intra-tester reliability check was conducted on 27 male runners prior to testing. No significant difference between the 2 trials for the sum of 8 skin-folds was observed ($p > 0.05$). The intra-class correlation was high at $r = 0.95$. The same investigator was also compared to another trained investigator to determine objectivity. No significant difference existed between testers ($r = 0.97$; $p > 0.05$). The skin-fold measurements were taken once throughout the entire 8 skin-folds and then repeated 3 times by the same investigator; the mean of the 3 times was then used for the analyses. The timing of the taking of the skin-fold measurements was standardised to ensure reliability. According to Becque et al. [5], readings were performed 4 s after applying the calliper. For male athletes, percent body fat was calculated using the following anthropometric formula for men: Percent body fat = $0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(\text{age})$, where $\Sigma 7SF$ = sum of skin-fold thickness of pectoralis, axillar, triceps, subscapular, abdomen, suprailiacal and front thigh mean, according to Ball et al. [2]. This formula was evaluated using 160 men aged 18 to 62 years old and cross-validated using DXA (dual energy X-ray absorptiometry). The mean differences between DXA percent body fat and calculated percent body fat ranged from 3.0 % to 3.2 %. Significant ($p < 0.01$) and high ($r > 0.90$) correlations existed between the anthropometric prediction equations and DXA. For female athletes, percent body fat was calculated using the following anthropometric formula for women: Percent body fat = – 6.40665 + 0.41946(Σ3SF) – 0.00126(Σ3SF)^2 + 0.12515(hip) + 0.06473(age), according to Ball et al. [3]. Skeletal muscle mass was calculated using the following anthropometric formula: Skeletal muscle mass = Ht x (0.00744 x CAG^2 + 0.00088 x CTG^2 + 0.00441 x CCG^2) + 2.4 x sex – 0.048 x age + race + 7.8, where Ht = height, CAG = skin-fold-corrected upper arm girth, CTG = skin-fold-corrected thigh girth, CCG = skin-fold-corrected calf girth, sex = 1 for male and 0 for female, race = 0 for white, according to Lee et al. [12]. This anthropometric method was evaluated using 135 male and 109 female non-obese subjects and cross-validated using MRI (magnetic resonance imagining) evaluation. Since skeletal muscle mass is expressed in kg, we calculated fat mass from percent body fat and total body mass. Three months before the race, athletes were asked for their average weekly training volume in hours and kilometres per discipline over the last 3 months in the preparation for the race. During these 3 months prior to the race, each athlete maintained a comprehensive training diary consisting of daily workouts showing distance and duration per discipline. Furthermore, they indicated their number of finished marathons and their personal best time in a marathon.

Statistical analysis

Data is presented as mean (SD). The coefficient of variation of performance (CV % = 100 x SD/mean) for total race time and the split times was calculated. Anthropometric and training variables were compared between males and females by Kruskal-Wallis equality-of-populations rank test. The difference in speed in training compared to racing was investigated using Wilcoxon signed rank test. The Pearson correlation coefficient was used to test for univariate associations between race time including split times and anthropometric variables. Bonferroni correction was used to compensate for multiple testing effects. Significant p-values after Bonferroni correction were assumed at a level of <0.0026 (n=19 tests for the relationship between race time with the anthropometric variables body mass, body height, BMI, 3 limb circumferences, 8 single skin-fold thicknesses, the sum of upper body skin-fold thicknesses (pectoralis, axillar, triceps, subscapular, abdominal, suprailiacal), the sum of lower body skin-fold thicknesses (front thigh and medial calf), the sum of 8 skin-fold thicknesses, percent body fat and skeletal muscle mass).

Results

Race performance

The male winner completed the race in 8:25 h:min (505 min), the female winner in 9:20 h:min (560 min). Our male subjects finished the race within 697 (74) min (CV = 10.5 %), equal to 138 (15) % of the winning time. For the swim split, they invested 76 (16) min (CV = 21.0 %), for the bike 357 (39) min (CV = 10.9 %) and for the run 264 (38) min (CV = 14.4 %). The swim portion accounted for 10.9 (1.5) % of total race time, the bike split for 51.2 (3.3) % and the run split for 37.8 (3.7) %. The cycling split showed the highest correlation coefficient ($r = 0.82$, $p < 0.0001$) with total race time compared to the swim split ($r = 0.76$, $p < 0.0001$) and run split ($r = 0.74$, $p < 0.0001$). The females finished within 762 (88) min (CV = 11.5 %), equal to 136 % of the winning time. They completed the swim within 81 (13) min (CV = 16 %), the bike in 390 (41) min (CV = 10.5 %) and the run within 291 (41) min (CV = 14.1 %). The swim portion accounted for 10.7 (1.1) % of the total race time, the bike split for 51.2 (1.9) % and the run split for 38.0 (2.0) %. The split times in cycling ($r = 0.95$, $p < 0.0001$) and running ($r = 0.94$, $p < 0.0001$) showed roughly the same association with total race time; however, the swim split was of minor importance ($r = 0.79$, $p = 0.0002$). Males competed significantly faster in the bike split ($p < 0.05$) compared to females, but not in the swim and run split ($p > 0.05$) (**Table 2**).

Anthropometry in males and females

The anthropometric variables are summarised in **Table 1.** In males, body mass, body height, BMI and the circumferences of limbs were highly significantly higher compared to females. The thickness of the skin-folds at pectoralis was higher in males; at triceps, front thigh and medial calf, the skin-folds were thinner in males compared to females. The sum of 8 skin-fold thicknesses showed no difference between genders; however, males had both a lower sum of lower body skin-fold thicknesses and lower percent body fat compared to females. Skeletal muscle mass was highly significantly higher in male subjects compared to females. In both males ($r = -0.03$) and females ($r = -0.09$) percent body fat was not related to the average weekly training volume ($p > 0.05$).

Volume and intensity in training and racing for males and females

Table 2 represents the training in volume, intensity and speed during the race. Training volume covering average weekly hours and kilometres per discipline showed no difference between genders; however, male athletes were swimming and cycling faster during training compared to females. In males, average total weekly training volume and total race time showed no association; in females, these 2 variables were highly significantly related ($r = -0.68$; $p < 0.01$). During racing, in males, speed in swimming and cycling was significantly faster compared to training ($p < 0.01$); in running, speed was significantly slower in the race than during training in males ($p < 0.01$), but not in females. In females, speed in swimming during the race was highly significantly faster compared to training ($p < 0.01$); in cycling and running, no differences were found.

Association of anthropometric and training variables with race performance in males

In **Table 3**, the correlations between anthropometry and volume in training and intensity, respectively, in the race is summarised for males. BMI ($r = 0.64$; $p = 0.0003$), percent body fat ($r = 0.76$; $p < 0.0001$), the sum of 8 skin-fold thicknesses ($r = 0.71$; $p < 0.0001$) and the sum of upper body skin-fold thicknesses (**Figure 1**) were related to total race time. In addition, percent body fat ($r = -0.67$; $p = 0.0001$), the sum of 8 skin-fold thicknesses ($r = -0.59$; $p = 0.001$) and the sum of upper body skin-fold thicknesses (**Figure 2**) were associated with speed in cycling during the race. Male athletes with lower body fat finished the race highly significantly faster ($r = 0.76$; $p < 0.0001$). No relationship was found between the anthropometric variables and average weekly training volume in total, or in the sub disciplines. Percent body fat and the sum of 8 skin-fold thicknesses were not related to speed in training in the 3 sub disciplines. Average weekly training volume was not related to percent body fat ($r = -0.03$; $p > 0.05$). Age was related to both body fat (**Figure 3**) and total race time (**Figure 4**). Skeletal muscle mass showed a higher correlation to total body mass ($r = 0.84$, $p < 0.0001$) compared to fat mass ($r = 0.68$, $p = 0.0001$). Skeletal muscle mass showed no association with both volume during training and intensity during the race; but was significantly related to running time during the race (**Figure 5**). However, no association of skeletal muscle mass was found for split times during swimming and cycling in the race ($p > 0.05$).

Association of anthropometric and training variables with race performance in females

In females, neither age and percent body fat nor age and performance showed a relationship ($p > 0.05$). In addition, none of the investigated anthropometric variables showed an association with total race time, average weekly training volume or speed in sub disciplines in the race (**Table 4**). Speed in running during training was related to both percent body fat ($r = -0.53$; $p < 0.05$) ($r = -0.53$; $p < 0.05$) and to the sum of 8 skin-fold thicknesses ($r = -0.51$; $p < 0.05$) ($r = -0.51$; $p < 0.05$). Average weekly training volume was not related to percent body fat ($r = -0.09$; $p > 0.05$).

Personal best time in a marathon and marathon performance during the race

Twenty-one male subjects had finished at least one marathon with a personal best time of 200 (27) min. The time of 264 (38) min for the marathon during the Ironman was highly significantly slower ($p < 0.0001$) compared to the personal best marathon time; on average 31 (19) % slower. Personal best time in a marathon and split time for the marathon in the Ironman were moderately associated ($r = 0.47$; $p = 0.0248$). However, a personal best marathon time was not related to race time in the Ironman ($p > 0.05$). Thirteen females had finished at least one marathon with a personal best time of 225 (25) min. During the race, they invested 290 (41) min for the marathon, 27 (15) % slower ($p < 0.0001$) compared to their personal best time. Also for females, personal best time in a marathon and split time for the marathon in the Ironman were moderately associated ($r = 0.58$; $p = 0.0360$). Again in females, personal best marathon time was not related to race time in the Ironman ($p > 0.05$). Male athletes had a significantly better personal best time in marathon running compared to female athletes ($p < 0.05$).

Discussion

We found in male Ironman triathletes a highly significant association of upper body skin-fold thickness with both total race performance and performance in the bike split. This is in contrast to the findings of Arrese & Ostáriz [1] with elite long-distance runners, where low skin-fold thicknesses of the lower limb were highly significantly related to running performances over 1,500 m and 10,000 m. Furthermore, Arrese & Ostáriz [1] found a positive relationship between both the iliac crest and abdominal skin-fold thickness with marathon race time in females where we found no association between skin-fold thicknesses and performance in our females. Besides, the sum of 8 skin-fold thicknesses was related to race performance in our males, but not in the study of Arrese & Ostáriz [1].

One explanation could be the anthropometry of the subjects. Arrese & Ostáriz [1] investigated highly trained runners over distances between 100 m and the marathon. These runners had achieved running times among the best 50 ever in the Spanish ranking. To compare with our subjects, their male marathoners were 30 (4) years old and had a body mass of 60 (3) kg; the female marathoners were the same age and had a body mass of 45 (6) kg. The male runners in Arrese & Ostáriz [1] had a BMI of < 22 kg/m^2. Our male athletes were older and 17 kg heavier, our females were also older and 15 kg heavier. Eleven out of our 27 male athletes (40%) had a BMI > 25 kg/m^2; one of these 11 athletes had a BMI > 30 kg/m^2. In contrast, BMI was < 25 kg/m^2 in all our females. We assume that the positive correlation between body fat and race performance in males must be due to these different findings in BMI and body fat. Furthermore, our male athletes were older compared to the marathoners in the study of Arrese & Ostáriz [1] and therefore it is not astonishing that with the advanced age of our athletes body fat was increased (**Figure 3**) and a slower race time (**Figure 4**) resulted.

Arrese & Ostáriz [1] showed in elite male runners a relationship between skin-fold thickness in the lower limb and performance in running. In contrast, we found an association between skin-fold thickness of the upper body and speed in cycling during the race in our sub-elite males (**Figure 2**). This might be due to the fact that we investigated triathletes, who train and race in 3 different disciplines. Indeed, this finding might be a pure coincidence and not causal; however helping the athletes to perform better in the race. Our triathletes had to climb an altitude of 300 m 3 times during the bike split. We assume those athletes with less body fat were faster in the ascent compared to athletes with more body fat, although body mass showed no relationship with cycling performance. This hypothesis might be confirmed by the finding that body fat showed no relationship with swimming and running performance (**Table 4**). In swimming athletes have buoyancy in the water, and in running the course was completely flat. In addition, during the run, athletes were significantly slower compared to training. Presumably, after the bike part, athletes were tired and not able to run as fast as during training. Our findings might support the results from O'Toole et al. [16] that cycling performances seem to be of particular importance in long-distance triathlon since in Ironman triathletes the physique is most similar to that of cyclists regarding physiological parameters. This is reflected in the present race by the higher correlation coefficients for the bike split compared to the swim and run splits with total race time especially in male subjects.

Legaz & Eston [13] concluded from their study of high-level long-distance runners that the decrease in skin-fold thickness is due to intense training. We found no relationship between training and body fat since training expressed as volume in hours showed no relationship with body fat for males (**Table 3**) and females (**Table 4**). Presumably, the level of body fat might be determined by other factors such as diet, genetics, or intensity in training. Regarding the intensity in training, we found a faster training speed in swimming and cycling for male athletes (**Table 2**). Interestingly, for females, speed in running during training was related to percent body fat and the sum of 8 skin-fold thicknesses, but not in males. However, we found no relationship between skin-fold thicknesses in females and race performance or split performance as we did for our males.

We found a significant and positive association of percent body fat with race performance in males (**Table 3**), but not in females. Male athletes with lower body fat were faster in the race compared to athletes with higher body fat. One might assume that athletes with a high total body mass would also have also a high fat mass and carry around a large 'dead' mass, and skeletal muscle mass would be more important to develop power and increase speed in the race. In males, total body mass correlated with fat mass ($r = 0.68$, $p = 0.0001$); however, skeletal muscle mass showed a higher correlation to total body mass ($r = 0.84$, $p < 0.0001$). Regarding **Table 3**, percent body fat was highly significantly associated with race performance in males, whereas total body mass and skeletal muscle mass showed no correlation. Male athletes with a lower skeletal muscle mass finished the run split faster during the Ironman (**Figure 5**). We therefore deduce that low body fat is an important factor for performance in male Ironman triathletes. This is supported by recent findings in male Triple Iron triathletes, where the sum of 8 skin-fold thicknesses was related to total race time [7].

A further interesting finding is that both genders invested the same percentage of total race time for each sub discipline during the race. However, males competed faster in the bike split compared to females and completed the whole race faster than the females. Males were swimming and cycling faster during the race compared to training, but ran slower in the race compared to training. Females were swimming faster during the race compared to training; however, speed in cycling and running showed no differences in training compared to racing. Obviously, both males and females were tired after the bike and could not perform better in the run. Since males competed faster in the bike compared to females, they had obviously to go slower in the run as the females did. We assume that the lower body fat percentage in males compared to females (**Table 1**) led to the enhanced performance in the bike split (**Table 3**) for males. Low skin-fold thicknesses in males had no impact on running performance in the race since the athletes were exhausted and tired after the bike section.

In a recent study of male Triple Iron triathletes, the sum of 8 skin-fold thicknesses - but not percent body fat - was related to both the total race time and the speed in the run split during competition [7]. In that race, athletes invested 48.7 % of total race time in the bike split and 41.8 % in the run split. However, no associations between anthropometry and split times were performed. We assume that the slightly higher percentage of time in the run split explains why in male Triple Iron triathletes the sum of 8 skin-folds is related to speed in the run split compared to the actual findings of male Ironman triathletes, where skin-fold thicknesses are associated with bike performance.

In this present race, both males and females ran the marathon in the same speed and their run time was about 30 % slower compared to their personal best marathon time. Personal best time in a marathon was related in both males and females to the split time in the run portion of the race. However, personal best time was not related to total race time, as has been shown recently in ultra-runners in a 24 hour run [8]. We must assume that both male and female athletes were tired after the bike segment and again, male athletes were significantly faster in the bike split due to the lower body fat. However, there is still a discrepancy: To climb up the hills on the bike, we might assume that a lower body mass would enhance performance. However, neither in males (**Table 3**) nor females (**Table 4**) was total body mass related to total race time.

This study was performed using recreational athletes in contrast to the study of Arrese & Ostáriz [1] with elite runners. We have to point out that the divergent relationship between upper and lower body skin-folds with performance observed in this investigation might be due to the sample size and the anthropometry, age and fitness levels, respectively, of the athletes. The association between performance and skin-fold thickness may not reflect a causal effect. It has to be determined whether this association is due to training, diet or genetics. A longitudinal study to assess the influence of training on skin-fold thickness should be performed with a larger sample of Ironman triathletes. In addition, elite young male athletes with a BMI < 25 kg/m^2 should be included.

To conclude we found a relationship between BMI, the sum of 8 skin-fold thicknesses, the sum of upper body skin-fold thicknesses and percent body fat with total race time in male Ironman triathletes. The sum of 8 skin-fold thicknesses, the sum of upper body skin-fold thicknesses and percent body fat were also related to speed in cycling during the race. In contrast, skin-fold thicknesses were not associated with race time in females. The cross-sectional nature of the study prohibits assessment of cause and effect and therefore does not allow investigating the role of anthropometrics as a predictor of performance. Our cross-sectional results provide a sound hypothesis to further investigate this cheap and feasible method of anthropometric measurements as a useful tool for coaches and sport scientists. Actually, for practical applications, anthropometric findings may help to predict the ‘biological limit of performance’, where no further improvements in training and/or race performance can be expected. A further important finding is the difference between male and female athletes regarding the association between anthropometry and performance. To further investigate the causal role of training and anthropometrics and its interrelationship, and to elucidate the clinical relevance of gender differences on race performance, longitudinal studies are needed. The difference between males and females concerning the association between body fat and race performance evidenced by the present study needs more investigation.

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Anthropometric variables	Male athletes (n = 27)	Female athletes (n = 16)
Body mass (kg)	77.7 (9.8) **	59.7 (6.1)
Body height (cm)	178 (6) **	166 (6)
BMI (kg/m^2)	24.3 (2.2) **	21.5 (1.0)
Circumference upper arm (cm)	31.5 (2.9) **	26.7 (1.9)
Circumference thigh (cm)	56.0 (3.2) **	52.9 (3.1)
Circumference calf (cm)	38.1 (2.4) **	36.4 (2.1)
Skin-fold pectoralis (mm)	6.3 (4.6) **	3.6 (1.2)
Skin-fold axillar (mm)	8.1 (3.4)	7.0 (1.8)
Skin-fold triceps (mm)	6.9 (2.7) **	9.2 (2.0)
Skin-fold subscapular (mm)	9.9 (5.2)	7.7 (1.7)
Skin-fold abdominal (mm)	10.1 (9.8)	11.8 (3.6)
Skin-fold suprailiacal (mm)	13.8 (7.9)	13.1 (6.0)
Skin-fold thigh (mm)	11.5 (6.1) **	19.8 (8.5)
Skin-fold calf (mm)	7.5 (3.3) **	13.0 (5.1)
Sum of upper body skin-folds (mm)	60.1 (31.3)	52.4 (12.3)
Sum of lower body skin-folds (mm)	19.0 (8.0) **	32.8 (13.2)
Sum of 8 skin-folds (mm)	79.1 (36.4)	85.2 (24.0)
Percent body fat (%)	14.4 (4.8) **	22.8 (4.8)
Skeletal muscle mass (kg)	41.0 (4.7) **	28.0 (2.3)

Table 1: Comparison of the anthropometric properties of both the male and female athletes. Values are given as mean (SD). ** = $p < 0.01$.

Training and racing variables	Male athletes (n=27)	Female athletes (n=16)
Training volume (h/week)	14.8 (3.2)	13.9 (3.4)
Hours of swimming per week	2.5 (1.1)	2.4 (1.0)
Hours of cycling per week	8.0 (2.0)	7.5 (2.4)
Hours of running per week	4.2 (1.1)	4.0 (1.5)
Kilometres of swimming per week	6.7 (3.0)	5.5 (2.4)
Kilometres of cycling per week	220.5 (63.3)	192.3 (63.9)
Kilometres of running per week	45.0 (12.2)	41.7 (15.8)
Speed in training of swimming (km/h)	2.7 (0.6) *	2.2 (0.6)
Speed in training of cycling (km/h)	27.3 (3.0) *	25.3 (4.3)
Speed in training of running (km/h)	10.7 (1.4)	9.7 (2.9)
Speed in swimming during race (km/h)	3.1 (0.6) #	2.8 (0.5) #
Speed in cycling during race (km/h)	30.6 (3.1) * #	28.0 (2.9)
Speed in running during race (km/h)	9.8 (1.7) #	8.9 (1.3)

Table 2: Comparison of the training and race variables of both the male and female athletes. Results are presented as mean (SD). * = $p < 0.05$. # = $p < 0.01$ (comparison of speed in training compared to racing).

Anthropometric variables	Total race time	Training volume in swimming (km)	Speed in swimming during race (km/h)	Training volume in cycling (km)	Speed in cycling during race (km/h)	Training volume in running (km)	Speed in running during race (km/h)
Body mass (kg)	0.02	0.84	0.21	0.66	0.29	0.21	0.02
Body height (cm)	-0.12	0.10	0.23	0.02	0.21	0.18	-0.03
BMI (kg/m^2)	0.64; p=0.0003	0.02	-0.47	0.10	-0.41	0.17	-0.53
Circumference upper arm (cm)	0.55	0.08	-0.33	0.05	-0.32	0.24	-0.50
Circumference thigh (cm)	0.37	0.02	-0.23	0.20	-0.14	0.07	-0.41
Circumference calf (cm)	0.31	0.08	0.01	0.22	-0.19	0.14	-0.35
Skin-fold pectoralis (mm)	0.70; p<0.0001	0.18	-0.44	0.03	-0.63; p=0.0005	0.07	-0.36
Skin-fold axillar (mm)	0.77; p<0.0001	0.15	-0.54	0.07	-0.67; p<0.0001	0.06	-0.45
Skin-fold triceps (mm)	0.58; p<0.001	0.07	-0.31	0.15	-0.52	0.09	-0.35
Skin-fold subscapular (mm)	0.75; p<0.0001	0.07	-0.52	0.12	-0.63; p=0.0005	0.13	-0.38
Skin-fold abdominal (mm)	0.70; p<0.0001	0.20	-0.51	0.04	-0.57; p=0.0019	0.12	-0.41
Skin-fold suprailiacal (mm)	0.68; p<0.0001	0.13	-0.40	0.06	-0.55	0.14	-0.44
Skin-fold front thigh (mm)	0.44	0.00	-0.16	0.23	-0.41	0.01	-0.23
Skin-fold medial calf (mm)	-0.18	0.00	0.34	0.23	0.18	0.06	0.01
Sum of upper body skin-folds (mm)	0.75; p<0.0001	0.11	-0.50	0.16	-0.63; p=0.0004	0.14	-0.43
Sum of lower body skin-folds (mm)	0.27	0.47	0.02	0.09	-0.24	0.03	-0.17
Sum of 8 skin-folds (mm)	0.71; p<0.0001	0.13	-0.43	0.10	-0.59; p=0.001	-0.13	-0.41
Percent body fat (%)	0.76; p<0.0001	0.21	-0.53	0.04	-0.67; p=0.0001	-0.16	-0.41
Skeletal muscle mass (kg)	0.20	0.15	-0.02	0.19	0.01	0.34	-0.33

Table 3: The relationship between the anthropometric variables and total race time as well as average weekly training volume (km) and speed during the race (km/h) in the sub disciplines for the 27 male athletes. Results are presented as mean (SD). R-values are presented for all variables. In case of a significant relationship, the p-value is inserted.

Anthropometric variables	Total race time	Training volume in swimming (km)	Speed in swimming during race (km/h)	Training volume in cycling (km)	Speed in cycling during race (km/h)	Training volume in running (km)	Speed in running during race (km/h)
Body mass (kg)	-0.04	0.22	0.07	-0.30	0.14	-0.05	-0.25
Body height (cm)	-0.08	0.08	0.07	-0.26	0.10	0.21	-0.12
BMI (kg/m^2)	0.03	0.31	-0.01	-0.25	0.13	-0.44	-0.33
Circumference upper arm (cm)	0.08	0.28	0.08	-0.31	-0.34	-0.28	-0.34
Circumference thigh (cm)	0.01	0.18	0.06	-0.29	-0.03	-0.34	-0.33
Circumference calf (cm)	0.20	0.13	-0.11	-0.25	-0.09	-0.22	-0.45
Skin-fold pectoralis (mm)	-0.08	0.10	0.03	0.26	0.14	0.22	-0.08
Skin-fold axillar (mm)	0.20	0.08	-0.17	-0.22	-0.25	0.21	-0.23
Skin-fold triceps (mm)	0.26	0.10	-0.03	-0.29	-0.26	-0.09	-0.43
Skin-fold subscapular (mm)	0.29	0.10	-0.05	-0.37	-0.22	-0.24	-0.51
Skin-fold abdominal (mm)	0.00	-0.02	0.01	-0.02	-0.01	-0.07	-0.17
Skin-fold suprailiacal (mm)	0.09	-0.02	-0.03	-0.02	-0.09	-0.30	-0.23
Skin-fold front thigh (mm)	-0.16	0.41	0.24	0.14	0.23	-0.34	-0.10
Skin-fold medial calf (mm)	-0.07	0.44	0.16	0.34	0.13	-0.18	-0.13
Sum of upper body skin-folds (mm)	0.15	0.22	-0.05	-0.14	-0.14	-0.16	-0.34
Sum of lower body skin-folds (mm)	-0.13	0.43	0.22	0.22	0.20	-0.29	-0.11
Sum of 8 skin-folds (mm)	0.00	0.35	0.11	0.05	0.02	-0.24	-0.26
Percent body fat (%)	0.01	0.36	0.12	-0.07	0.03	-0.31	-0.27
Skeletal muscle mass (kg)	0.02	0.18	0.06	- 0.28	0.17	- 0.09	- 0.22

Table 4: The relationship between the anthropometric variables and total race time as well as average weekly training volume (km) and speed during the race (km/h) in the sub disciplines for the 16 female athletes. Results are presented as mean (SD). R-values are presented for all variables. No significant associations have been found.

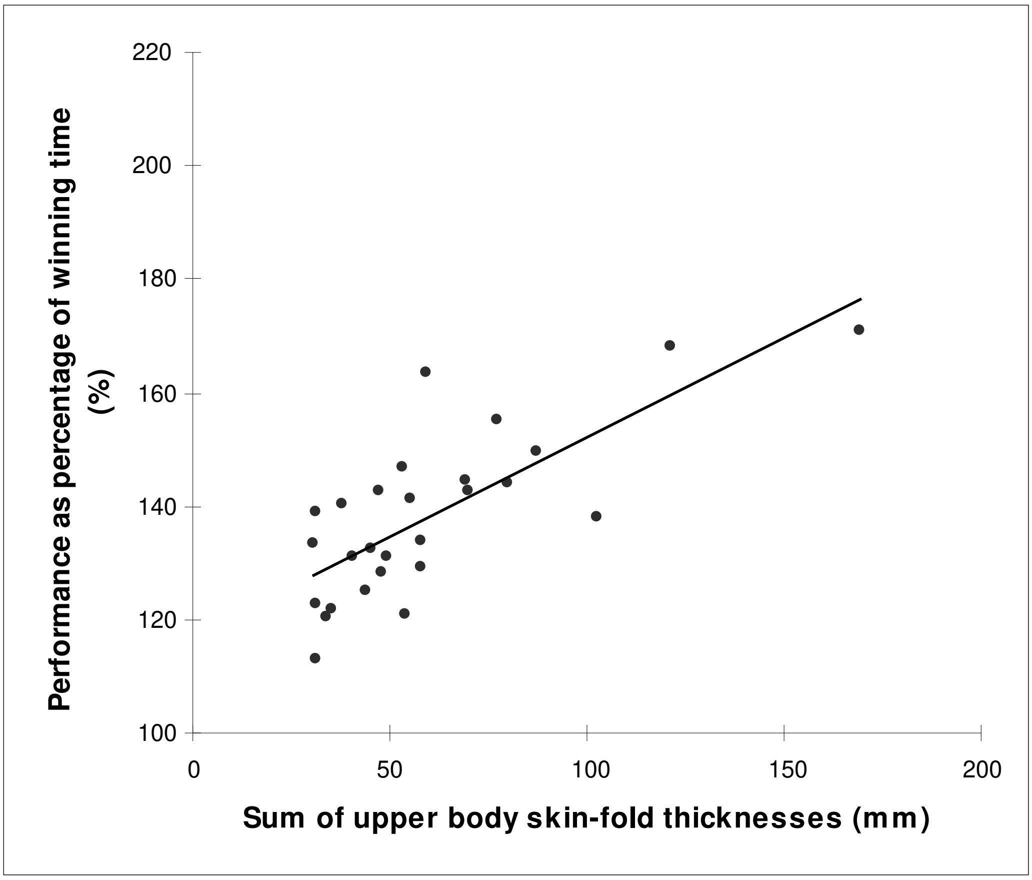

Figure 1: Male athletes with a lower sum of upper body skin-fold thicknesses finished the race faster (n = 27) (r = 0.75, $p < 0.0001$).

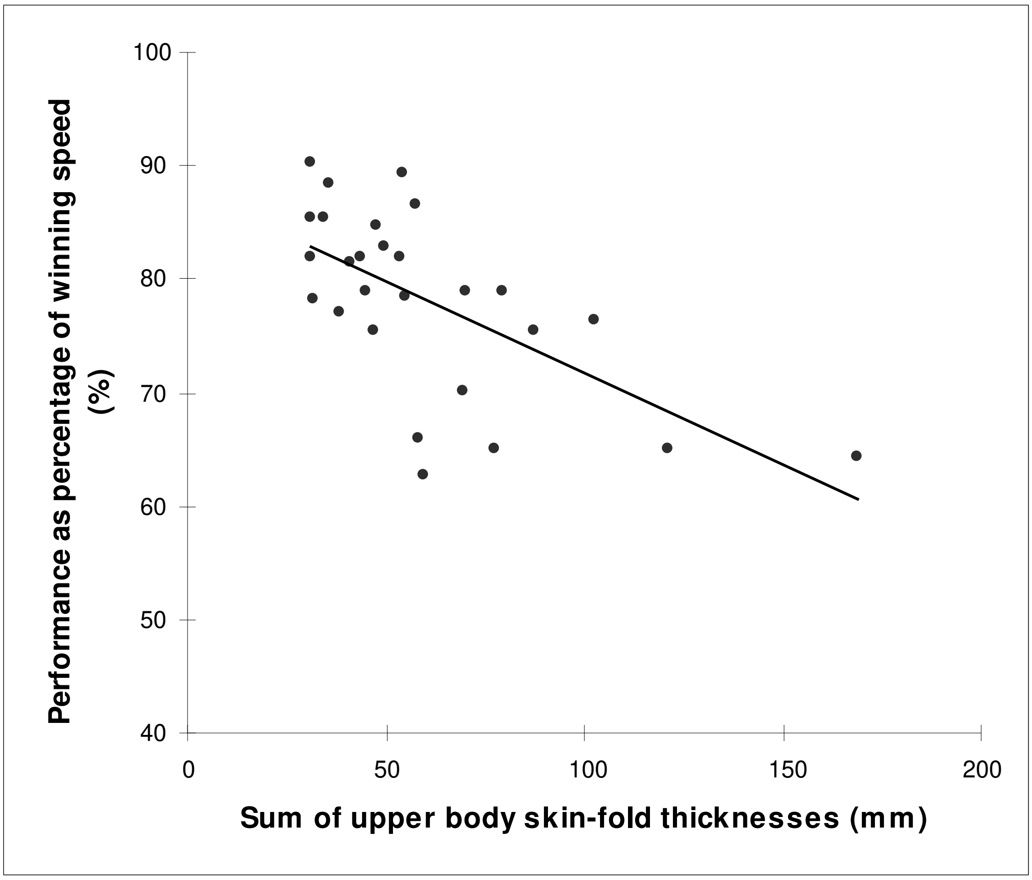

Figure 2: Male athletes with a lower sum of upper body skin-fold thicknesses competed faster in the bike split during the race (n = 27) (r = –0.63; p = 0.0004).

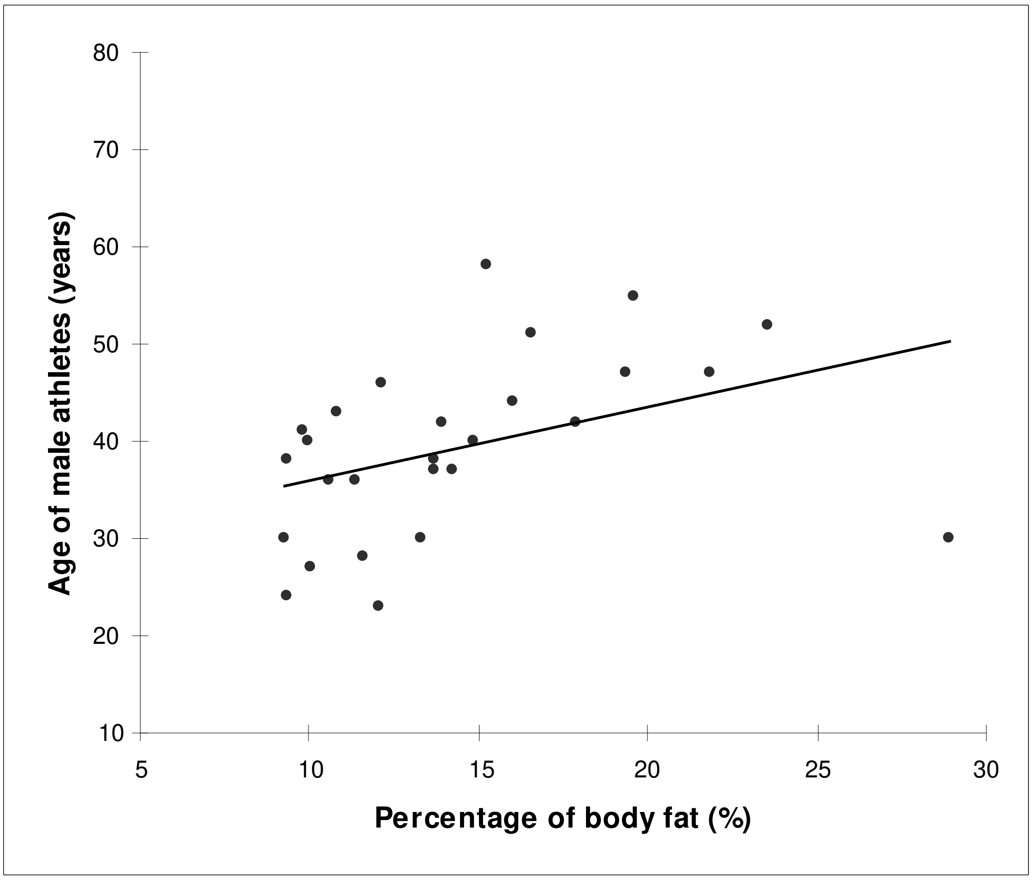

Figure 3: In males, age was related to percent body fat (n = 27) (r = 0.40; p = 0.0369)

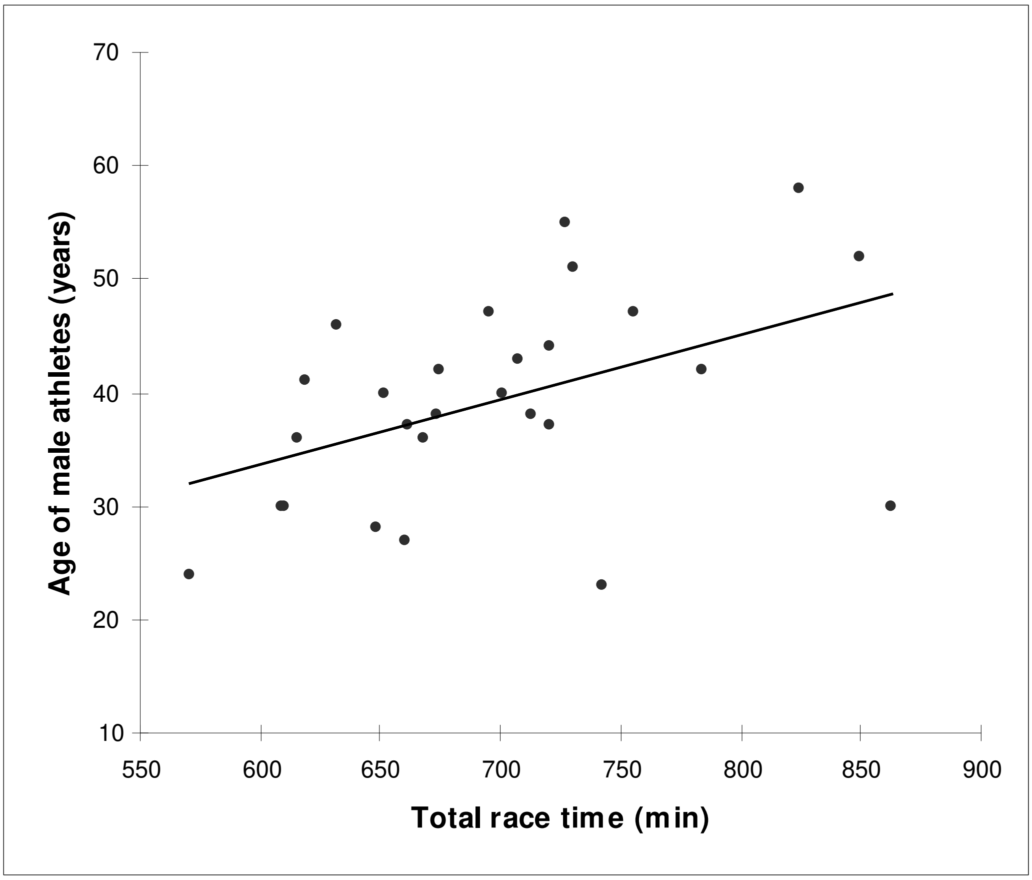

Figure 4: In males, age was related to total race time (n = 27) (r = 0.46; p < 0.05).

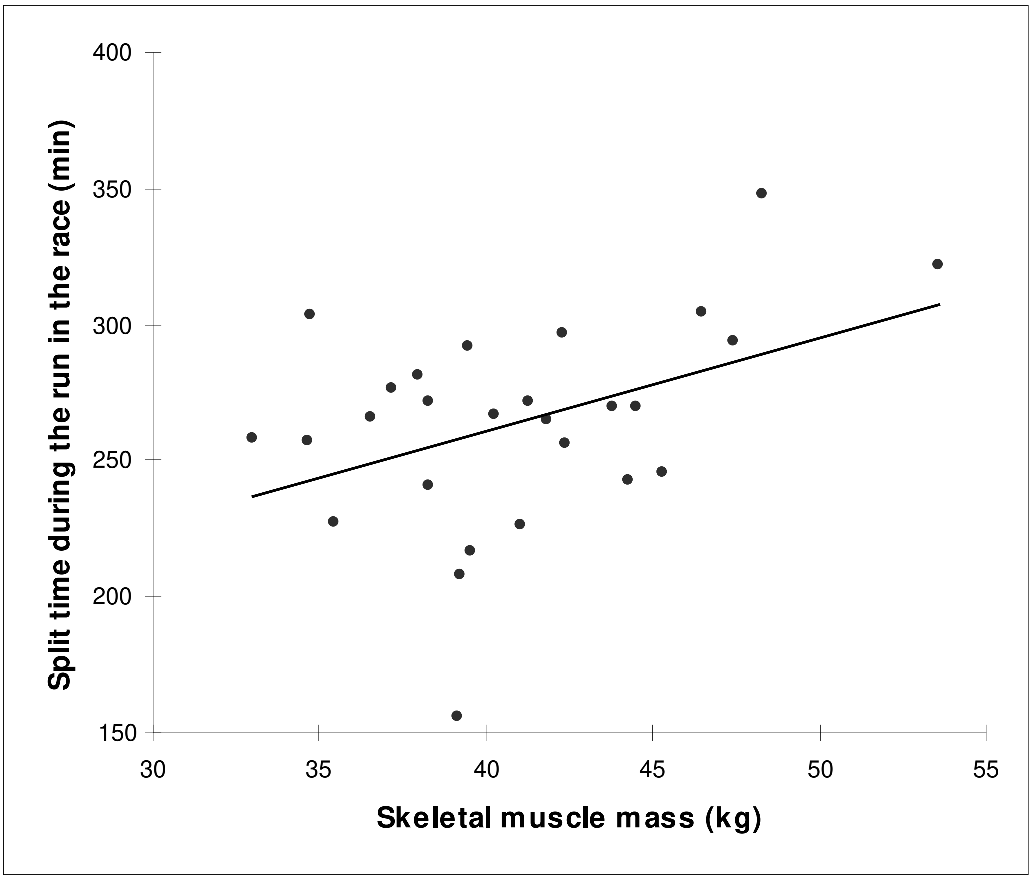

Figure 5: Skeletal muscle mass was significantly and positively related to running time during the race in male athletes (n=27) (r = 0.42; p = 0.0278).